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Estimated Magnitude of Sea Turtle Interactions and Mortality in US Bottom Trawl Gear, 2014-2018

US DEPARTMENT OF COMMERCE
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ABSTRACT

This paper reports total estimated interactions and mortalities of loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) sea turtles in bottom otter trawl gear operating in the US Mid-Atlantic and Georges Bank regions from 2014-2018. Interaction rates for each turtle species were estimated with stratified ratio estimators, where rates were stratified by Ecological Production Unit (Georges Bank and Mid-Atlantic), latitude zone, season, and depth. In the Mid-Atlantic region, a total of 571 loggerhead (CV = 0.29, 95% CI = 318-997), 46 Kemp's ridley (CV = 0.45, 95% CI = 10-88), 16 green (CV = 0.73, 95% CI = 0-44), and 20 leatherback (CV = 0.72, 95% CI = 0-50) turtle interactions were estimated to have occurred in bottom trawl gear over the 5 year period. On Georges Bank, 12 loggerheads (CV = 0.70, 95% CI = 0-31) and 6 leatherback (CV = 1.0, 95% CI = 0-20) interactions were estimated to have occurred. Approximately 272 loggerhead interactions, 23 Kemp's ridley interactions, 8 green interactions, and 13 leatherback interactions resulted in mortality over the 5 year period. Roughly 2,668 sea days would be needed annually to monitor loggerhead interactions with 30% precision across bottom trawl fleets in the Mid-Atlantic, based on results of this analysis. Monitoring levels were not estimated for Kemp's ridley, leatherback, or green turtles in this analysis, nor for loggerheads on Georges Bank, because of their low probability of capture. Monitoring for these other turtles and on Georges Bank would still occur, but the targeted level of monitoring would be driven by other marine species groups.

INTRODUCTION

All sea turtles in the United States (US) are protected under the Endangered Species Act (ESA). To assess the impact of US commercial fishing on turtle populations which overlap fishing activity in space and time, information is needed on the anticipated magnitude of sea turtle interactions in commercial fishing gear. The US Mid-Atlantic region is important foraging habitat for loggerhead (*Caretta caretta*) turtles in summer months (Griffin et al. 2013; Patel et al. 2016). Predicted densities of loggerheads vary over the Northeast Continental Shelf from late spring to early fall as animals migrate into and out of the region from Cape Hatteras and points farther south (Winton et al. 2018). Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) turtles also inhabit parts of the Mid-Atlantic or Georges Bank throughout the year (Morreale et al. 2005; TEWG 2000, 2007). During these times sea turtles interact with a variety of commercial gear types (Murray 2018, 2015a, 2015b). For instance, from 2009–2013, roughly 230 loggerheads were estimated to have interacted with bottom trawl gear each year, of which 96 were estimated to result in mortality (Murray 2015b).

In this analysis, an incidental "interaction" between turtles and commercial gear is synonymous with an ESA take, defined as, "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA 1973). Generally, these interactions include animals that are brought onboard the fishing vessel by the gear or that interact with the gear at the surface, but some interactions also occur subsurface or away from view (Warden and Murray 2011). This analysis also reports a portion of these unobservable interactions, which in this case are animals that escape through a turtle excluder device (TED) (Murray 2015b). TEDs are required on summer flounder trawlers (50 CFR 222.102) in certain times and areas in

the summer flounder/sea-turtle protection area between Cape Charles, VA, and the North Carolina/South Carolina border (Figure 1 in U.S. Department of Commerce 1996).

To help assess the impact of removals on the population, estimated interactions and mortalities for loggerheads are also expressed in terms of adult-equivalent losses. Adult equivalency translates the loss of individual turtles into the number of adults expected based on chances of the individual surviving to adulthood and reproducing. Compared to individual losses, monitoring adult-equivalent losses from fisheries interactions can be a more informative metric to assess population-level impacts (Haas 2010; Warden et al. 2015) and allows for a common currency to compare the impacts of removals across life stages or different gear types.

This paper reports the total estimated interactions and mortalities of sea turtles in bottom otter trawl gear operating in the US Mid-Atlantic and Georges Bank regions from 2014-2018. A portion of the interactions includes an estimate of the number of turtles escaping through a TED. Turtle species include: the Northwest Atlantic distinct population segment of loggerhead sea turtle, Kemp's ridley, leatherback, and green turtle. In addition, this paper reports the monitoring levels necessary in future sampling years to estimate interaction rates between loggerheads and commercial fishing gear with a 30% precision goal.

METHODS

Data Sources

Observer Data

Data collected by Northeast Fisheries Observer Program (NEFOP) observers and at-sea monitors (ASM) aboard vessels using bottom trawl gear[1] from 2014 through 2018 were used to compute interaction rates of loggerhead, Kemp's ridley, leatherback, and green turtles. In this analysis, a total of 5,227 days fished was observed from 2014-2018 in bottom trawl fisheries in the Georges Bank and Mid-Atlantic, which represented 13% of commercial trawl fishing effort across both regions (Table 1; Figure 1). In the Georges Bank region, NEFOP data comprised 54% of observed days fished, and ASM data comprised 46%; in the Mid-Atlantic region, NEFOP data comprised 92% of observed days fished, and ASM data comprised 8%. In the area where NEFOP and ASM coverage overlapped (north of 39ºN), there were no major differences in the seasons or depth zones where NEFOP and ASM sampling occurred (Figures 2 and 3).

Commercial Data

Mandatory Vessel Trip Reports (VTRs) completed by commercial trawl fishermen from 2014 - 2018 provided a measure of total fishing effort. Effort was expressed as the amount of fishing time in units of 24 hour periods (days fished), computed as:

(Average tow time [hrs] per haul * number of hauls)/24

Vessels using bottom trawl gear completed a total of 38,724 days fished from 2014-2018 in the Georges Bank and Mid-Atlantic regions.

[1] Takes in the southern Mid-Atlantic shrimp twin trawl fishery were not included in this analysis because takes in this fishery are estimated by the Southeast region, and NE observers no longer observe this fishery. This gear was identified as (Observer Database System [OBDBS] negear code = 050 and nettype = 33, 34, or 35), or negear code = 450.

Interaction Rates

Interaction rates for each turtle species were estimated with stratified ratio estimators. This method differs from previous approaches (Murray 2015b; Warden 2011), where rates were estimated with generalized additive models (GAMs). Ratio estimators have the advantage of being computationally simple with general application to many sampling designs (Cochran 1977) and can yield results similar to those using GAMs or generalized linear models (GLM) if ratio estimators are stratified based on the same explanatory variables in a GAM or GLM model (Murray 2007, 2013; Orphanides 2009).

Observer and commercial data were stratified by Ecological Production Unit (Georges Bank and Mid-Atlantic), latitude zone, season, and depth, based on factors associated with loggerhead bycatch rates in previous trawl bycatch analyses (latitude, sea surface temperature, depth) (Murray 2015b, 2006; Warden 2011). Within the Mid-Atlantic Ecological Production Unit (EPU), latitude zones included: Northern (>=37ºN to the Mid-Atlantic boundary), Middle (>37ºN and <39ºN), and Southern (<=37ºN). Season was used as a proxy for sea surface temperature [SST] and defined as summer (July – October) or winter (November – June). Depth groups were defined as shallow (<= 50m) or deep (> 50m). Within the Georges Bank Ecological Production Unit, rates were stratified by only season and depth groups. While only a few interactions occurred in the Georges Bank region, I stratified it as a separate region for a number of reasons: (1) each ecological region is characterized by distinct patterns in oceanographic properties, fish distributions, and primary production (Ecosystem Assessment Report 2012); (2) previous analyses of turtle interactions delineated the "Mid-Atlantic" with the same boundaries, and my stratification facilitates comparisons across time series; and (3) observer coverage is allocated separately across fleets operating in the Mid-Atlantic versus Northeast regions, of which Georges Bank is a part.

There have been no previous bycatch analyses of sea turtle species besides loggerheads to inform a stratification scheme for this analysis. The stratification for loggerheads was maintained for the other turtle species (Kemp's ridley, leatherback, green) because it was assumed to capture the temporal and spatial presence of each species on the Northeast continental shelf.

Within each stratum (j), interaction rates (R) were defined as:

$$R_j = \sum_{i=1}^{n} \frac{observed\ turtles_j}{observed\ days\ fished_j}$$

where n = the number of observed NEFOP and ASM hauls

Bootstrap resampling was used to estimate uncertainty (coefficient of variation [CV] and confidence intervals [CIs]) around interaction rates within each stratum, with trips as the resampling unit (Orphanides and Hatch 2017). Bootstrap replicates were generated by resampling trips with replacement 1000 times from the original observer dataset, and then bycatch rates within each stratum were computed for each replicate. The 95% CI for the bycatch rates were computed from the upper 97.5% and lower 2.5% quartiles of the bootstrap replicates. CVs and CIs for combined strata within the Mid-Atlantic and Georges Bank regions were also obtained in the same manner through the summation of stratum-specific bycatch estimates.

Excluder devices

Hauls that used TEDs were excluded from the analysis (n=55, or 0.11% of observed hauls) because they are designed to have different catch rates of turtles and there were no observed turtles on hauls with TEDs to allow for estimation of an observable interaction rate. Therefore, the bycatch rate reflected only the observable, non-TED interaction rate. It is not required that fishers report use of a TED on VTR logbooks, so VTR trips were assumed to be using a TED if they were operating within the times and areas of the sea turtle/summer flounder protection area during seasons when TEDs are required and if they landed more than 45kg (100 lbs) of summer flounder (*Paralichthys dentatus*) (CFR 222.102) (105 trips, or 0.13% of VTR trips).

Total Estimated Interactions/Mortality

Within each stratum, observed interaction rates were multiplied by total days fished from VTR trips to calculate the estimated number of turtle interactions. For VTR trips with TEDs, estimated interactions of hard-shelled turtle species were proportioned into observable interactions (those that passed through the TED into the cod end), and unobservable/quantifiable interactions (those that escaped out through the TED opening). On TED trips in each stratum, observable interactions were 3% of total estimated interactions, and unobservable/quantifiable interactions were 97% of total estimated interactions, based on a 97% experimental exclusion rate (Watson 1981).

Total observable mortalities were estimated by applying the mortality rate (50%)[2] for turtles observed in trawl gear interactions from the most recent time series available (2013-2017, in Upite et al. 2018) to the total estimated observable interactions. The mortality rate for unobservable yet quantifiable interactions was assumed to be 0% (Murray 2015b).

Adult Equivalency for Loggerheads

To estimate adult equivalent loggerhead interactions, each observed take with a curved carapace measurement was assigned reproductive value (RV) based on slow-growth high fecundity RVs in Wallace (2008). RVs represent the contribution of individuals within an age-class to current and future reproduction, taking into account age-structured survival rates and current and future fecundity. The estimated interactions on each VTR trip were then multiplied by the average RV for the trip's latitude zone (<= 37ºN: RV = 0.56 [n=5]; > 37ºN and < 39ºN: RV = 0.26 [n=7]; >= 39ºN: RV = 0.12 [n=26]) (Murray 2015b; Warden 2011). Total interactions of other turtle species were not translated into adult equivalency because RV values for these other species are not known.

Estimated Sea Day Needs

Prior to estimating observer coverage needs for future fishing years, the probability of encountering each turtle species in either the Georges Bank or Mid-Atlantic region was estimated by using results of this analysis. This approach is necessary to ensure that observer coverage in the upcoming year is not driven by imprecise estimates of interaction rates owing to an extremely rare event (US Dep of Commerce 2019a). The probability of observing 1 or more turtle species, assuming a Poisson distribution (Smith 1999), was estimated for varying amounts of observer

[2] This rate is slightly higher than the mean mortality rate in trawl gear reported for 2013-2017 (48%) because takes in shrimp twin trawl gear were excluded to be consistent with this analysis.

coverage based on the average annual number of interactions and VTR trips using bottom trawl gear in each respective region from 2014-2018. A similar evaluation was conducted for observer coverage in Mid-Atlantic sink gillnet fleets (US Dep of Commerce 2019a); sea days were only estimated and allocated for monitoring a turtle species in gillnet gear if there was >50% probability of observing 5 or more turtles over 800 trips in a year.

In this study, if the probability of encounter met this same threshold, then the sea days needed to monitor turtle interaction rates were estimated. Uncertainty (CVs) around the interaction rates were used to estimate the number of observer sea days needed in 2020 to achieve 30% CV precision around the interaction rate. A 30% precision goal has been recommended by the National Working Group on Bycatch (NMFS 2004) and is the standard used for sea day estimation needs under the Standard Bycatch Reporting Methodology Omnibus Amendment (Wigley et al. 2012).

The number of observed sea days needed to achieve a 30% coefficient of variation (CV) around interaction rates from 2014-2018 were computed as:

$$n_{proj} = (CV_{obs} * \sqrt{n_{obs}}/CV_{proj})^2$$

where n_{proj}= the number of projected trips (converted to sea days[3]); CV_{obs} = the precision levels around estimated interaction rates in this analysis; n_{obs}= the observed number of trips underlying the interaction rates; and CV_{proj} = the projected precision levels.

RESULTS

Characteristics of Observed Turtle Interactions

From 2014-2018, NEFOP observers documented 50 loggerhead turtle interactions in bottom trawl gear, 48 of which occurred in the Mid-Atlantic (Table 1; Figure 1)[4]. No turtles were documented by at-sea monitors. Observers also recorded 5 Kemp's ridley turtles, 3 leatherback turtles, and 2 green turtles. Eighty-three percent of the observed interactions occurred between July – October. Observers recorded the following range of curved carapace lengths (CCL) and carapace widths (W) for each species: loggerheads: 51.0-119.0 cm CCL (n = 38) and 48.3 – 80.0 cm W; Kemp's ridley: 22.7-29.7 cm CCL (n = 3) and 23.0-29.2 cm W; leatherbacks: 142.0 and 223.0 cm CCL (n = 2) and 91.5 and 153.0 cm W; green: 25.6 and 31.0 cm CCL (n=2) and 22.2 and 26.8 cm W.

Interaction Rates

The highest loggerhead interaction rate (0.43 turtles/day fished) was in waters south of 37ºN from November – June in waters deeper than 50m (Table 2; Figure 4). However, the greatest

[3] The conversion from trips to sea days used 2.3 mean days absent/trip, and 1 day absent = 1 sea day. Conversions were based on characteristics of VTR trawl trips in the Mid-Atlantic from 2014 – 2018.

[4] One of these included a turtle that could not be identified to species, but for this analysis it was presumed to be a loggerhead based on characteristics described by observers. The observer noted it was "dark brown, tannish with 5 vertebral scutes and an estimated length of 91cm."

number of estimated interactions occurred in the Mid-Atlantic region north of 39ºN, from July – October in waters less than 50m deep (Figure 4) because of a greater amount of commercial effort in this stratum compared to those farther south. Within each stratum, interaction rates for non-loggerhead species were lower than those for loggerheads (Table 2).

Total Estimated Interactions / Adult Equivalents

Loggerheads

From 2014-2018, 12 (CV = 0.70, 95% CI = 0-31 in GB) and 571 (CV = 0.29, 95% CI = 318-997 in MA) loggerheads were estimated to have interacted with bottom trawl gear (Table 3). The total number of turtle interactions across both regions was equivalent to 182 adults. An estimated 272 turtles (87 adult equivalents) were estimated to have died from these interactions. In the Mid-Atlantic, 38 loggerheads were estimated to have been excluded by TEDs.

Non-loggerheads

From 2014-2018, 46 (CV = 0.45, 95% CI = 10-88) Kemp's ridley and 16 (CV = 0.73, 95% CI = 0-44) green turtles were estimated to have interacted with bottom trawl gear in the Mid-Atlantic, of which 23 and 8 resulted in mortality, respectively. There were 0 turtles estimated to have been excluded by TEDs. In addition, 6 (CV = 1.0, 95% CI = 0-20) and 20 (CV = 0.72, 95% CI = 0-50) leatherback interactions were estimated to have occurred on Georges Bank and in the Mid-Atlantic, which resulted in 13 mortalities.

Estimated Sea Day Needs

Monitoring levels were not estimated for Kemp's ridley, leatherback, or green turtles in this analysis, nor for loggerheads on Georges Bank because there was <50% probability of observing 5 or more turtles over 800 trips in a year (Figures 5 and 6). Roughly 2,668 sea days would be needed annually to monitor loggerhead interactions with 30% precision across bottom trawl fleets in the Mid-Atlantic, based on results of this analysis.

DISCUSSION

The estimated number of interactions of loggerhead turtles in Mid-Atlantic bottom trawl gear has reduced from 353 per year from 2005-2008 (Warden 2011), to 231 per year from 2009-2013 (Murray 2015b), to 114 per year from 2014-2018. Since this is the first reported estimate of turtle interactions on Georges Bank, comparisons to previous time series are not possible. In this analysis, the highest number of estimated interactions occurred north of 39°N, which is farther north than in previous years. Interaction rates were highest in the southern Mid-Atlantic (south of 37°N), as they were in previous years (Murray 2015b; Warden 2011).

Unlike previous analyses, this analysis reports total estimated interactions of non-loggerhead turtle species in bottom trawl gear, as well as interactions outside of the Mid-Atlantic. In the past, total interactions for a species or within an ecological region were not estimated if there were too few observed events to support the modeling approach taken in the analysis (Murray 2015b). Total interactions of non-loggerhead species and on Georges Bank are reported here by using a different approach (a stratified ratio-estimator), though uncertainty around the rates are relatively high because there were so few observed turtles. Precision around turtle interaction rates may improve depending on levels of observer coverage and the abundance and distribution of turtles in the strata.

Observer coverage to monitor turtle interactions is typically integrated with coverage to monitor 14 assemblages of fish and invertebrate species across 38 fishing fleets in the Mid-Atlantic region (US Dept of Commer 2019b). In this analysis I only estimate the monitoring levels needed to achieve 30% precision around the interaction rates for loggerheads. This method means that for non-loggerhead species, monitoring will still occur, albeit not at levels that aim for 30% precision. This approach tries to balance coverage needs for a variety of marine species, directed at the more commonly discarded species. Non-loggerhead species in the Mid-Atlantic and all turtle species on Georges Bank were filtered from the estimated sea day needs because they did not meet the threshold that there be >50% probability of observing 5 or more turtles over 800 trips in a year. This threshold was recommended by the Standardized Bycatch Reporting Methodology Fishery Management Action Team (US Dep of Commerce, 2019a).

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Table 1. Observed days fished, Vessel Trip Reports (VTR) days fished, and observed turtle species in bottom trawl gear 2014-2018 in the Mid-Atlantic (MA) and Georges Bank (GB) regions. Cc = Loggerhead (*Caretta caretta*); Lk = Kemp's ridley (*Lepidochelys kempii*); Dc=Leatherback (*Dermochelys coriacea*); Cm=Green (*Chelonia mydas*).

Year	Region	Observed Days Fished	VTR Days Fished	% Observer Coverage	Observed Cc	Observed Lk	Observed Dc	Observed Cm
2014	GB	548	2,637	21%	1	0	0	0
	MA	710	6,547	11%	20	1	0	1
2015	GB	445	2,501	18%	0	0	0	0
	MA	547	5,786	9%	10	3	0	1
2016	GB	257	1,909	13%	0	0	0	0
	MA	624	5,791	11%	7	0	1	0
2017	GB	352	1,750	20%	1	0	1	0
	MA	768	5,159	15%	4	0	0	0
2018	GB	233	1,514	15%	0	0	0	0
	MA	743	5,130	14%	7	1	1	0
Total	GB	1,835	10,311	18%	2	0	1	0
	MA	3,392	28,413	12%	48	5	2	2
Total		5,227	38,724	13%	50	5	3	2

Table 2. Stratified interaction rates and coefficient of variation (CV) for each turtle species in bottom trawl gear 2014-2018. Only those strata with non-zero interaction rates are listed. MA = Mid-Atlantic; GB = Georges Bank. Cc = loggerhead (*Caretta caretta*); Lk = Kemp's ridley (*Lepidochelys kempii*); Dc = leatherback (*Dermochelys coriacea*); Cm = green (*Chelonia mydas*).

Region	Latitude Zone	Season	Depth	Cc rate (CV)	Lk rate (CV)	Dc rate (CV)	Cm rate (CV)
GB	N/A	July – Oct	<= 50m	0.004 (0.70)	0	0.002 (1.0)	0
MA North	>=39ºN	July – Oct	<= 50m	0.025 (0.24)	0.006 (0.49)	0.003 (0.72)	0.002 (1.0)
	>=39ºN	July – Oct	> 50m	0.050 (0.33)	0	0	0
	>=39ºN	Nov-Jun	<= 50m	0.003 (0.71)	0	0	0
	>=39ºN	Nov-Jun	> 50m	0.001 (0.68)	0	0	0
MA Mid	>37ºN & <39ºN	July – Oct	<= 50m	0.259 (0.52)	0.052 (1.02)	0	0.052 (1.0)
	>37ºN & <39ºN	July – Oct	> 50m	0.022 (0.55)	0	0	0
	>37ºN & <39ºN	Nov – Jun	> 50m	0.003 (0.99)	0	0	0
MA South	<=39ºN	Nov – Jun	<= 50m	0.231 (1.01)	0	0	0
	<=39ºN	Nov – Jun	> 50m	0.428 (0.68)	0	0	0

Table 3. Total estimated turtle interactions in bottom trawl gear 2014-2018 in the Georges Bank (GB) and Mid-Atlantic (MA) regions. Cc = loggerhead (*Caretta caretta*); Lk = Kemp's ridley (*Lepidochelys kempii*); Dc = leatherback (*Dermochelys coriacea*); Cm = green (*Chelonia mydas*). Values in brackets represent the additional amount of estimated interactions where turtles escaped out of a turtle excluder device (TED) opening. CV = Coefficient of variation, CI = 95% confidence interval.

Year		Total Cc Interactions	Total Lk Interactions	Total Dc Interactions	Total Cm Interactions
2014	GB	3	0	1	0
	MA	140 [13]	12	5	5
2015	GB	3	0	2	0
	MA	126 [6]	10	5	3
2016	GB	1	0	1	0
	MA	110 [11]	8	3	3
2017	GB	3	0	1	0
	MA	84 [4]	8	4	2
2018	GB	2	0	1	0
	MA	73 [4]	8	3	3
Total (CV, 95% CI)	GB	12 (0.70, 0-31)	0	6 (1.0, 0-20)	0
	MA	571 (0.29, 318-997)	46 (0.45, 10-88)	20 (0.72, 0-50)	16 (0.73, 0-44)
Average Annual (95% CI)	GB	2 (0-6)	0	1 (0-4)	0
	MA	114 (64-199)	9 (2-18)	4 (0-10)	3 (0-9)

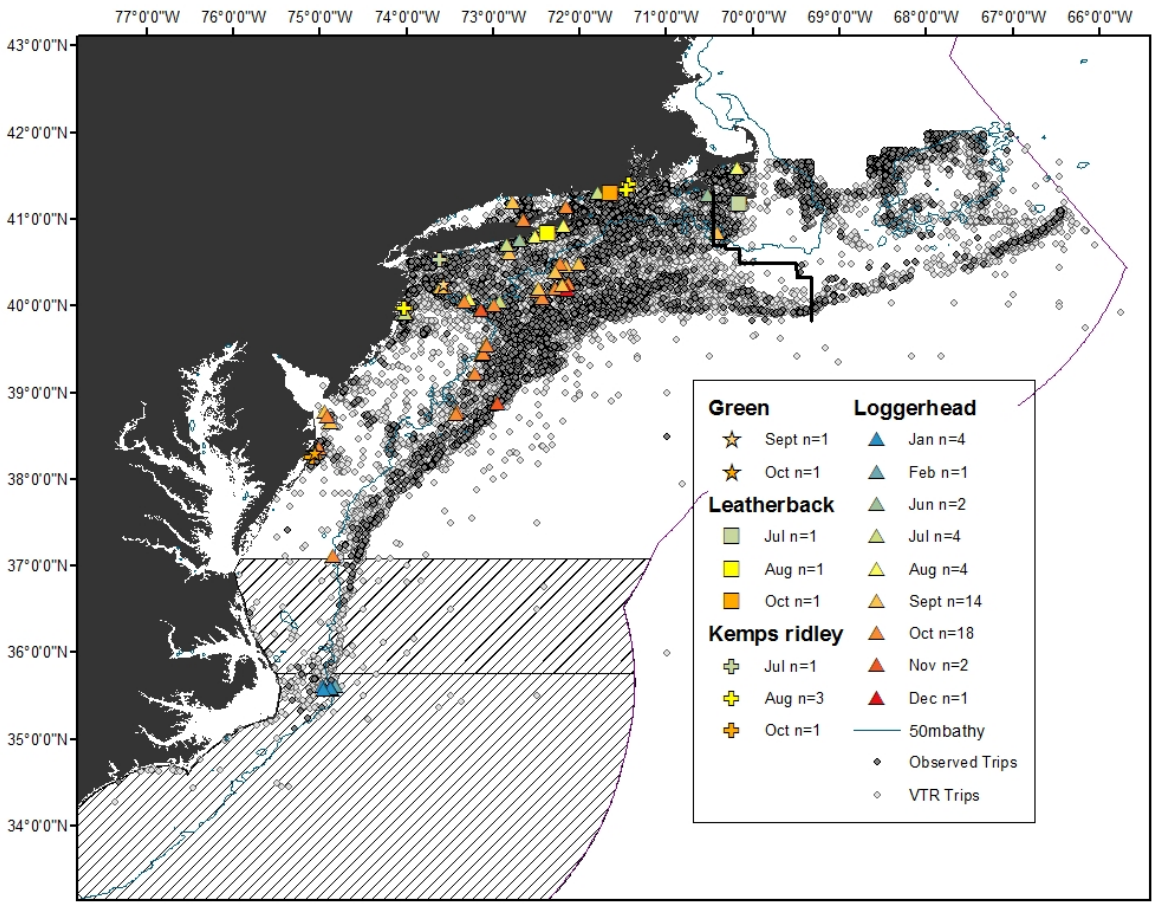

Figure 1. Observed loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) turtle interactions, observed trips, and commercial trips in US bottom trawl gear from 2014 to 2018 throughout Georges Bank and the Mid-Atlantic. The boundary between the Georges Bank and Mid-Atlantic Ecological Production Units is shown by the solid black line. The hatched lines depict the summer flounder/sea turtle protection area.

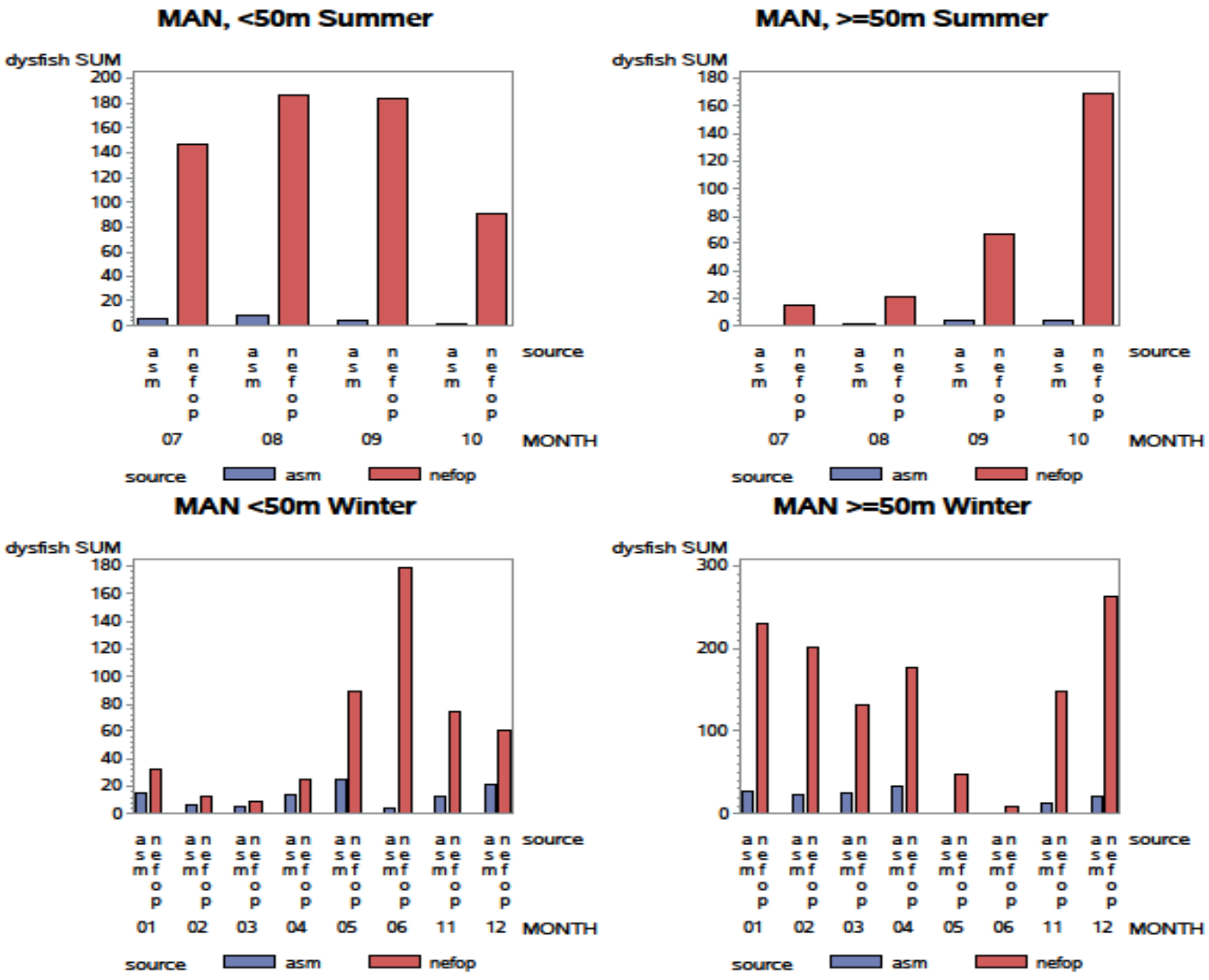

Figure 2. Spatial and temporal distribution of Northeast Fisheries Observer Program (NEFOP) and at-sea monitors (ASM) monitoring effort (days fished) in bottom trawl fisheries, 2014-2018. "MAN" = Mid-Atlantic North (>39N to Georges Bank line), dysfish = days fished.

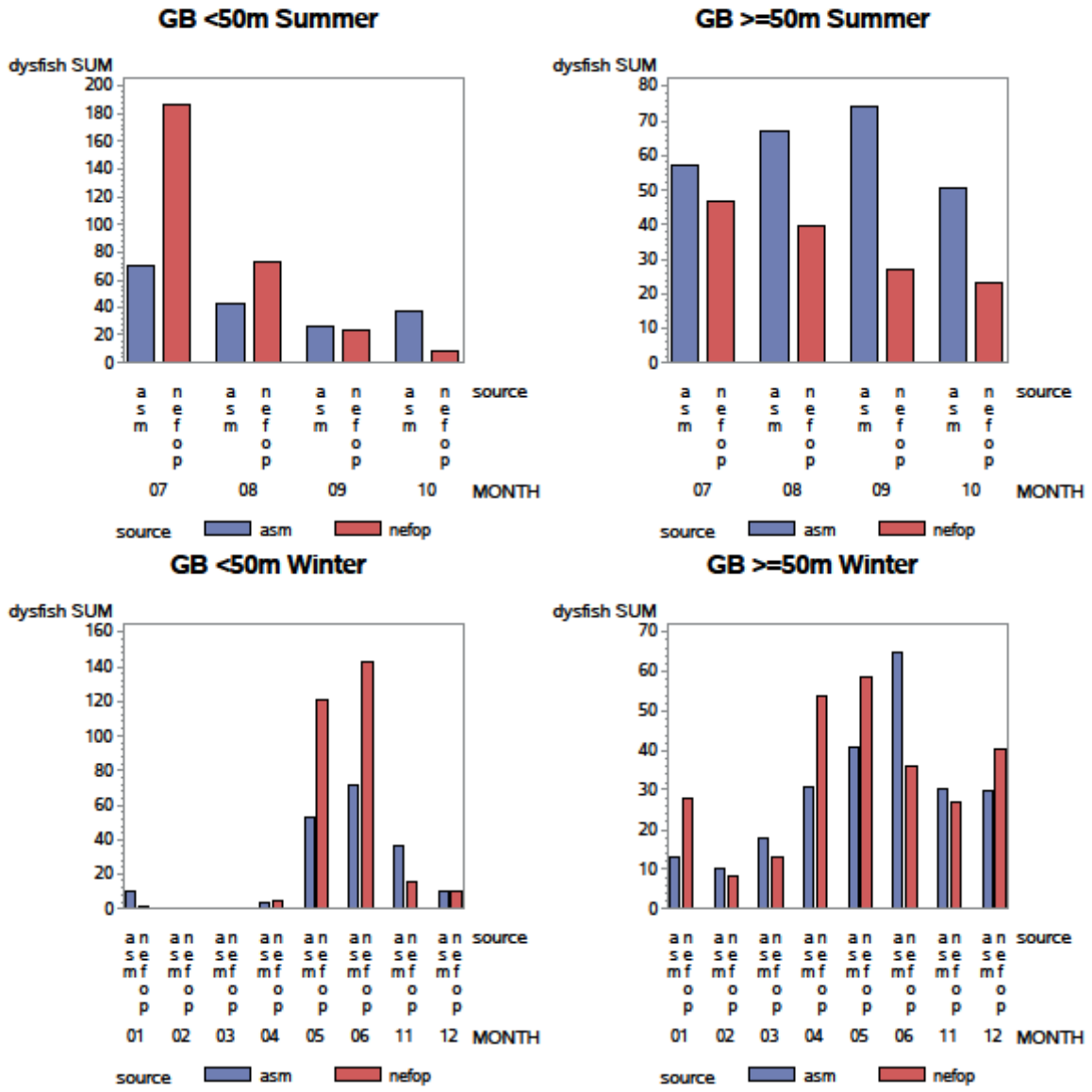

Figure 3. Spatial and temporal distribution of Northeast Fisheries Observer Program (NEFOP) and at-sea monitors (ASM) monitoring effort (days fished) in bottom trawl fisheries, 2014-2018. GB = Georges Bank, dysfish = days fished.

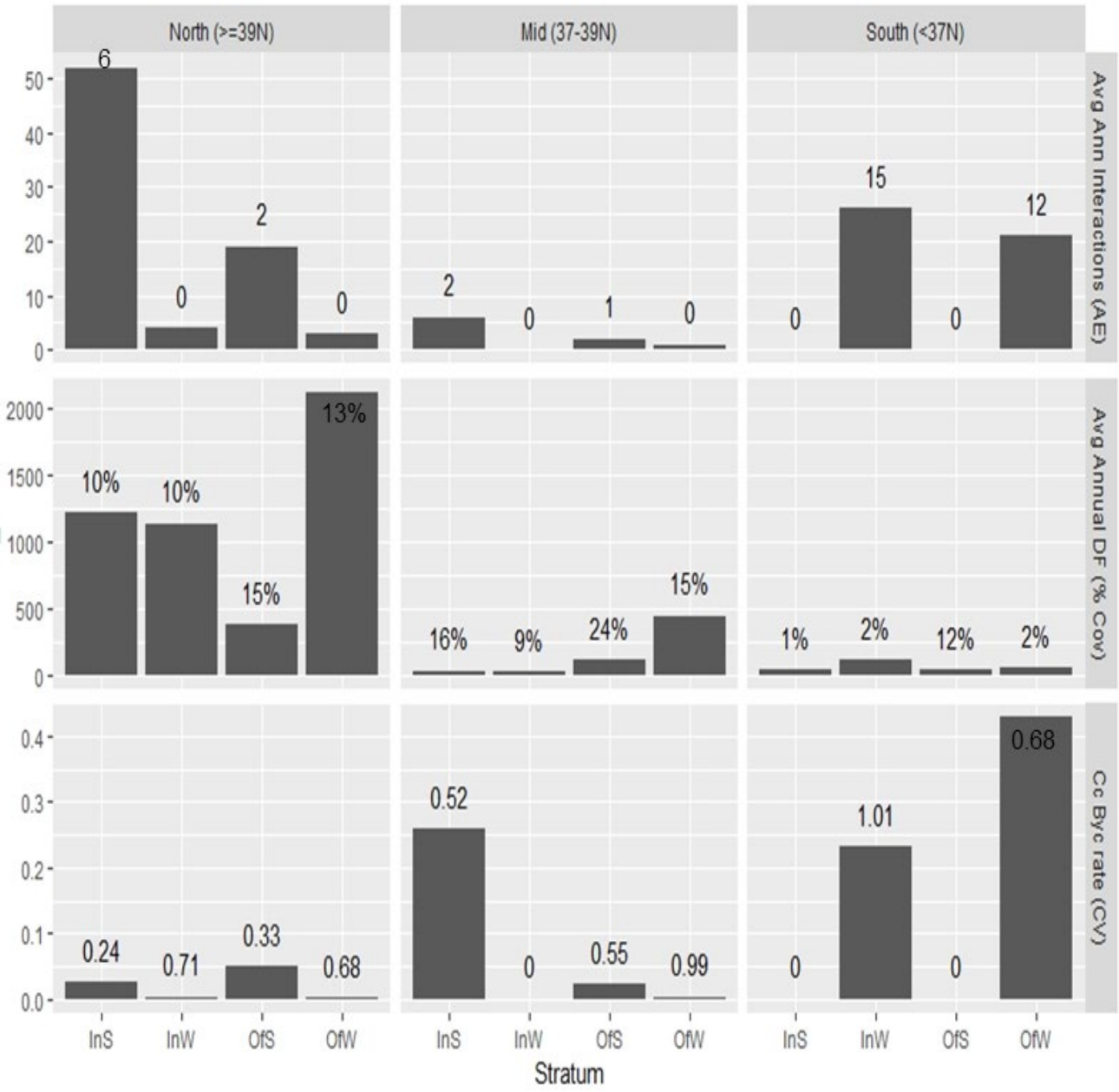

Figure 4. Average annual loggerhead (*Caretta caretta*) interactions (observable plus unobservable/quantifiable); average annual commercial effort; and loggerhead bycatch rates in Mid-Atlantic bottom trawl gear from 2014-2018, stratified by latitude zone, depth, and season. "InS": <= 50m July-Oct; "InW": <= 50m Nov-Jun; "OfS": > 50m July-Oct; "OfW": > 50m Nov-Jun. Values above the columns within each row: Adult Equivalent Interactions (AE); % Observer Coverage (in terms of days fished); Coefficient of Variation (CV).

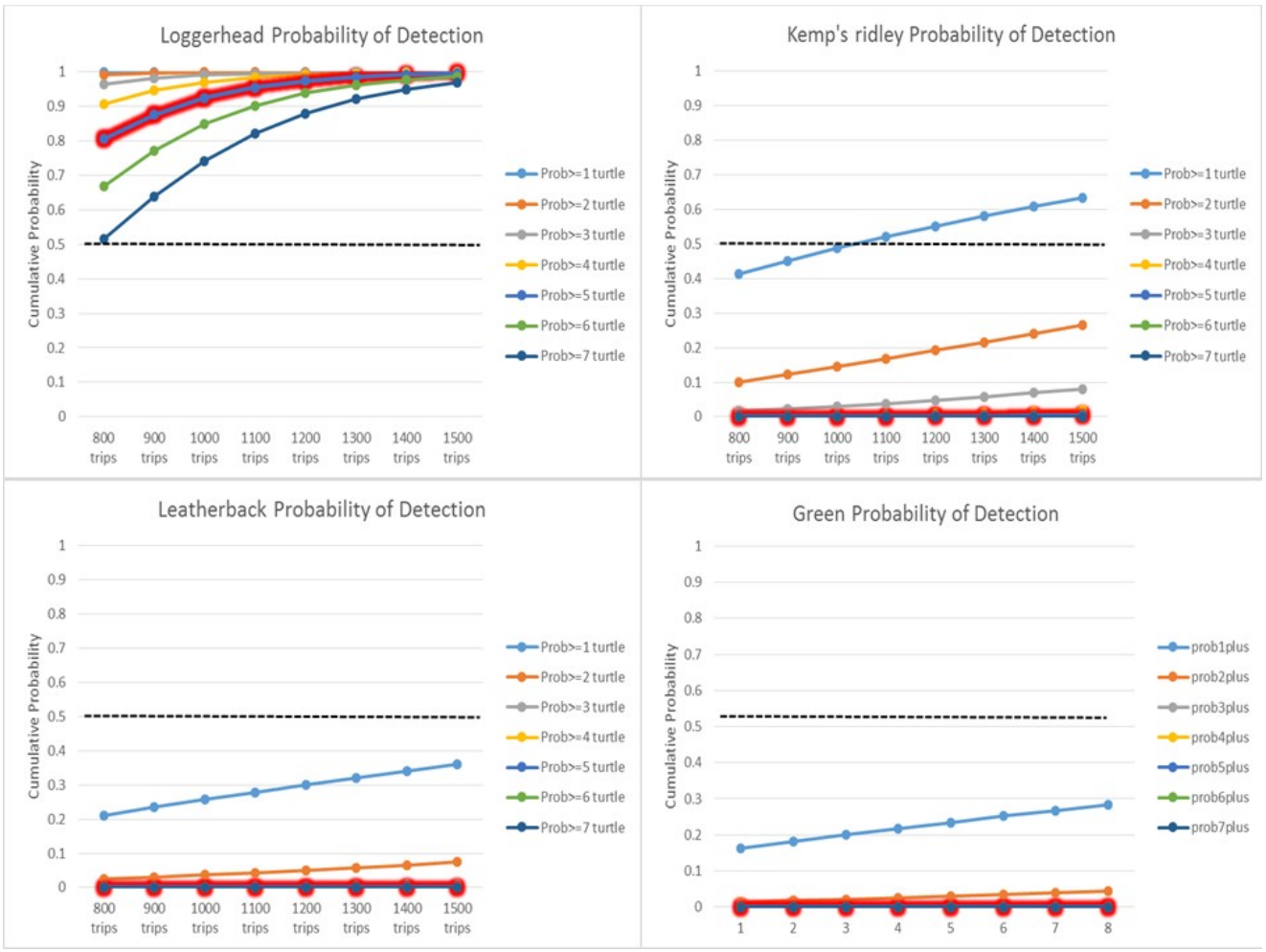

Figure 5. Cumulative probability of detecting numbers of loggerhead (*Caretta caretta*), Kemp's ridley (*Lepidochelys kempii*), leatherback (*Dermochelys coriacea*), and green (*Chelonia mydas*) sea turtles given various levels of annual observer coverage in bottom trawl gear, based on annual levels of commercial effort and total interactions in the Mid-Atlantic 2014-2018. Species are filtered from the sea day estimation if there is < 50% probability (dashed horizontal line) of observing >= 5 turtles (red highlighted line) over 800 trips in a year (US Dep of Commerce 2019a).

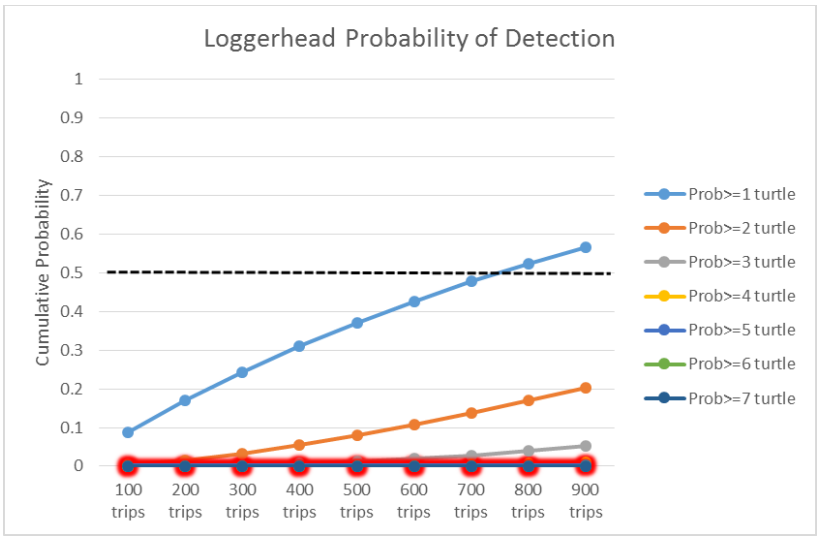

Figure 6. Cumulative probability of detecting numbers of loggerheads (*Caretta caretta*) given various levels of annual observer coverage in bottom trawl gear, based on annual levels of commercial effort and total interactions on Georges Bank 2014-2018.

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